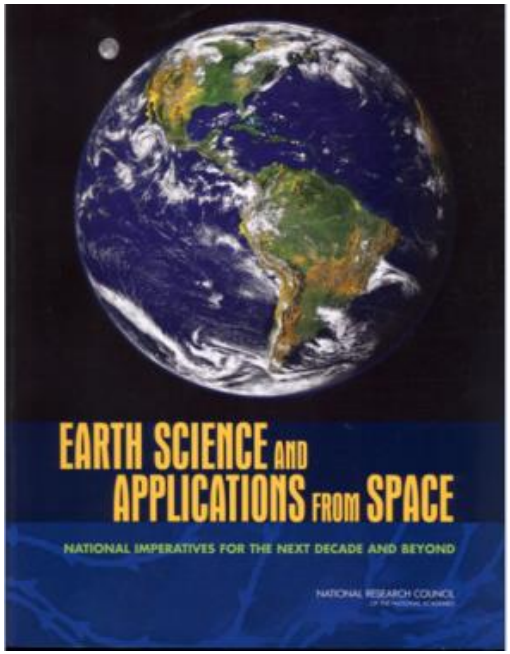
HysplRI
Comprehensive Mission Report



Robert O. Green and the HysplRI Community

2014 HyspIRI Guidance

1. Continue to build broad community understanding and support by conducting science and applications workshops and data product symposia;

2. Complete the science white paper specifying the value of the individual science measurements and the potential science return of individual instruments on separate platforms, including the ISS, if appropriate;

3. Use the planned airborne activities and resulting data to generate HyspIRI-like Level 2 data products (e.g., large-area 60m data sets providing surface reflectance, surface temperature and surface emissivity) to define the instrument capabilities
and explore high-volume data management issues related to the HyspIRI VSWIR and TIR instruments. These efforts should include additional support for airborne mission management.

4. Carry out instrument mission trade studies, including smallsat and ISS opportunities, to provide lower cost and more adaptable instrument and/or mission approaches. The team should consider conducting TEAM-X or IDL studies to assist with this, in addition to enlisting the support of ESTO and the ESM SEWG.

5. Explore options to ensure the HyspIRI VSWIR and TIR instruments meet the Sustainable Land Imaging measurement requirement, including compatibility with heritage data product resolution.

6. Engage potential international and domestic partners in addressing opportunities to lower the cost of a potential mission while maintaining Level 1mission requirements.

7. Support the Earth Systematic Missions (ESM) Systems Engineering Working Group (SEWG) studies on TRL definition and instrument cost studies;

8. Complete a comprehensive development report of the HyspIRI mission study activities as detailed below.

Outline for Comprehensive Mission Report

HyspIRI 2008-2013 Activities and Products Report

Contents

Pre-Formulation Personnel & Affiliations

- Woody Turner, Program Scientist, NASA HQ
- John LaBrecque, Program Scientist, NASA HQ
- Elizabeth Edwards, Flight Programs, NASA HQ
- Robert Green, Concept Co-Lead, JPL
- Simon Hook, Concept Co-Lead, JPL
- Elizabeth Middleton, Concept Co-Lead, GSFC
- Carl Bruce, Concept Manager, JPL
- Michael Mercury, Concept System Engineer, JPL
- Ernesto Diaz, Concept System Engineer, JPL
- Stephen Ungar, Concept Team Member, GSFC/USRA
- Kevin Turpie, Concept Team Member, GSFC
- Daniel Mandl, Intelligent Payload Module (IPM), GSFC
- Paula Bontempi, Coastal Ocean Science, NASA HQ
- Diane Wickland, Carbon Cycle and Ecosystems Science, NASA HQ
- Matthew Fladeland, Suborbital, ARC
- Charles Norton, ESTO, JPL
- Reggie Eason, Program Management, GSFC
- Petya Campbell, Concept Team Member, GSFC
- and the broader HyspIRI research, applications, and technology communities

HyspIRI Science Study Group
(Selected by NASA Program Science Leadership)

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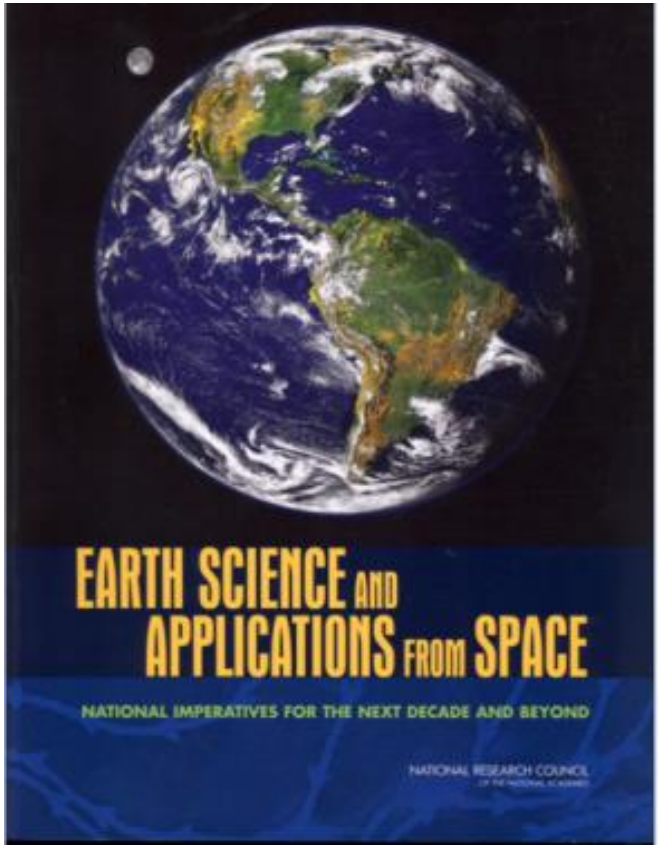


HyspIRI Science Questions VSWIR, TIR and Combined

- VQ1 – Pattern and Spatial Distribution of Ecosystems and their Components, Dar Roberts, Betsy Middleton,
- VQ2 – Ecosystem Function, Physiology and Seasonal Activity, John Gamon
- VQ3 – Biogeochemical Cycles, Scott Ollinger
- VQ4 – Changes in and Responses to Disturbance, Greg Asner, Bob Knox
- VQ5 – Ecosystems and Human Well-being, Phil Townsend, Greg Glass
- VQ6 – Earth Surface and Shallow Water Bottom Composition, Rob Green, Heidi Dierssen

- TQ1 – Volcanoes and Earthquakes, Mike Abrams, Friedmann Freund
- TQ2 – Wildfires, Louis Giglio
- TQ3 – Water Use and Availability, Martha Anderson, Rick Allen
- TQ4 –Urbanization and Human Health, Dale Quattrochi, Greg Glass
- TQ5 – Surface composition and Change, Anupma Prakash, John Mars

- CQ1 – Coastal, ocean, and inland aquatic environments, Frank Muller-Karger
- CQ2 – Wildfires, Louis Giglio
- CQ3 – Volcanoes, Robert Wright, Vince Realmuto
- CQ4 – Ecosystem Function and Diversity, Dar Roberts, Martha Anderson
- CQ5 – Land surface composition and change, Lyle Mars, Anupma Prakash
- CQ6 – Human Health and Urbanization, Dale Quattrochi, Greg Glass

HyspIRI

Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; spectral albedo; carbon/dust on snow/ice; biomass burning; evapotranspiration

Ecosystems: *Global* biodiversity, plant functional types, physiological condition, and biochemistry including agricultural lands

Fires: Fuel status; fire frequency, severity, emissions, and patterns of recovery *globally*

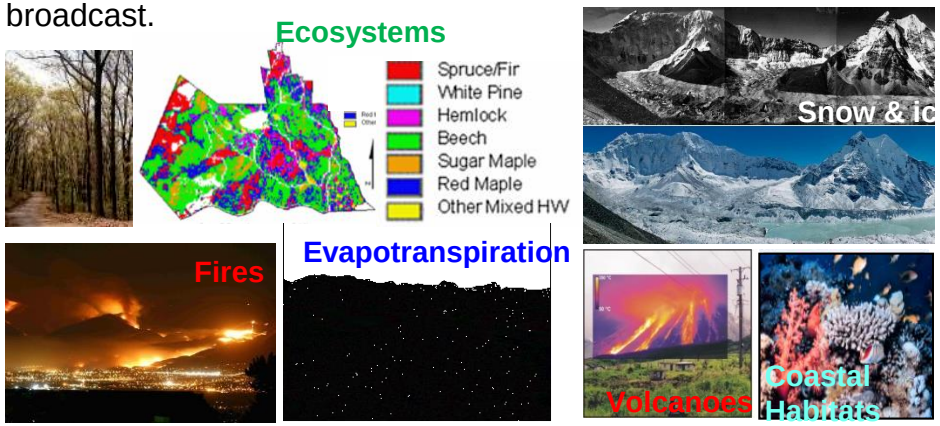
Coral reef and coastal habitats: *Global* composition and status

Volcanoes: Eruptions, emissions, regional and *global* impact

Geology and resources: *Global* distributions of surface mineral resources and improved understanding of geology and related hazards

Mission Urgency

The HyspIRI science and applications objectives are critical today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.



Measurement

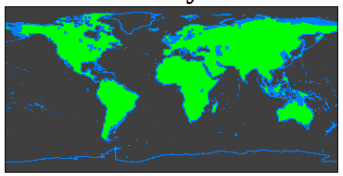
Imaging Spectrometer (VSWIR)

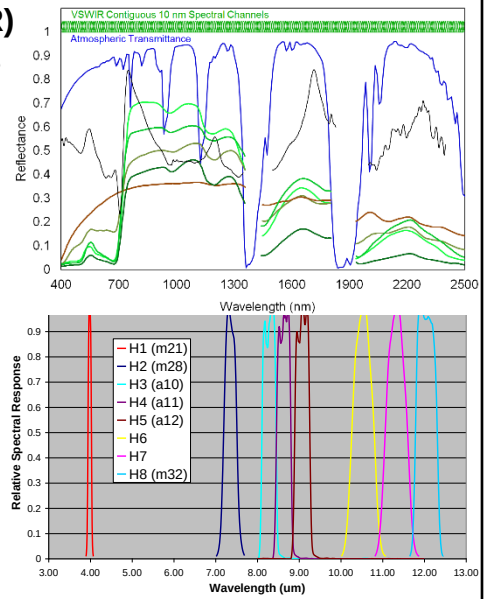
- 380 to 2500nm in 10nm bands
- 60 m spatial sampling
- 19 days revisit
- Global land and shallow water

Thermal Infrared (TIR):

- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit; day/night
- Global land and shallow water

IPM-Low Latency data subsets





Mission Concept Status

Level 1 Measurement Requirements: Vetted by community and stable

Payload: **VSWIR** Imaging Spectrometer, **TIR** Imaging radiometer, and **IPM**-Low Latency subsets

Full Mission option: Baseline mission mature with Aerospace Independent Cost Estimate

Options for Technology/Science ISS Demonstration: Submitted for VSWIR and TIR with IPM

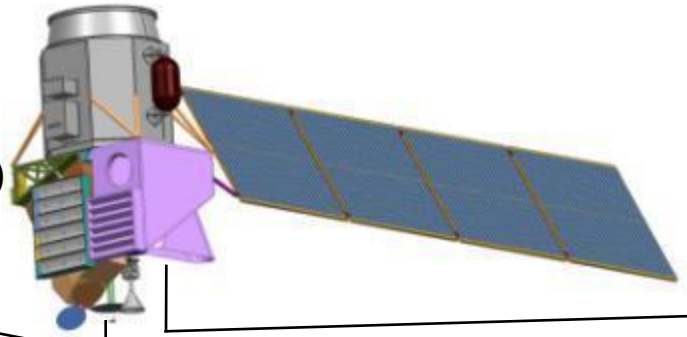
Studies for instrument on separate platforms: Science whitepaper

Summary: The HyspIRI mission measurement requirements and baseline instruments approach are mature and stable with good heritage, low risk and modest cost. Now exploring a range of instrument and data options to save cost, per guidance letter.

Dedicated Combined Polar Orbiter

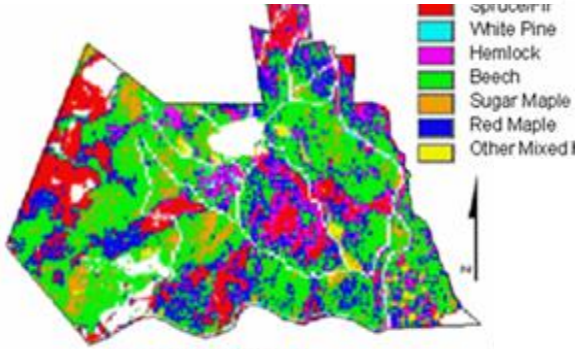
Earth Science and Science Applications
Global: Climate Change, Impact, Adaptation, & Vulnerability

Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer

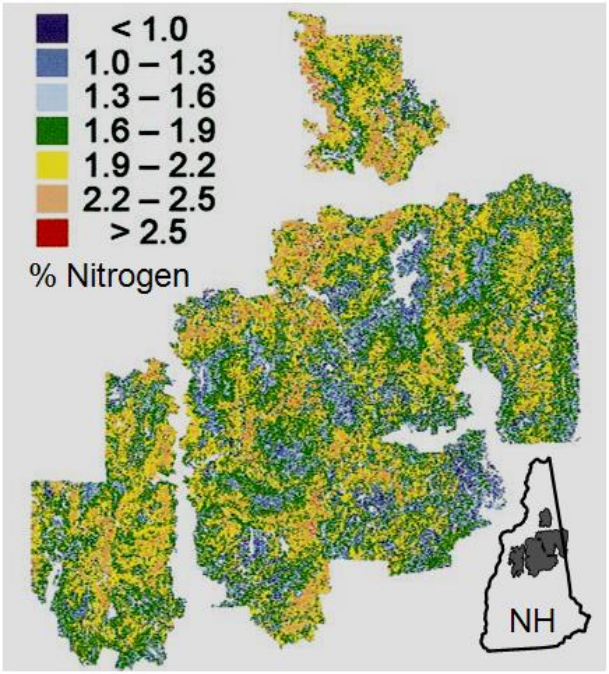


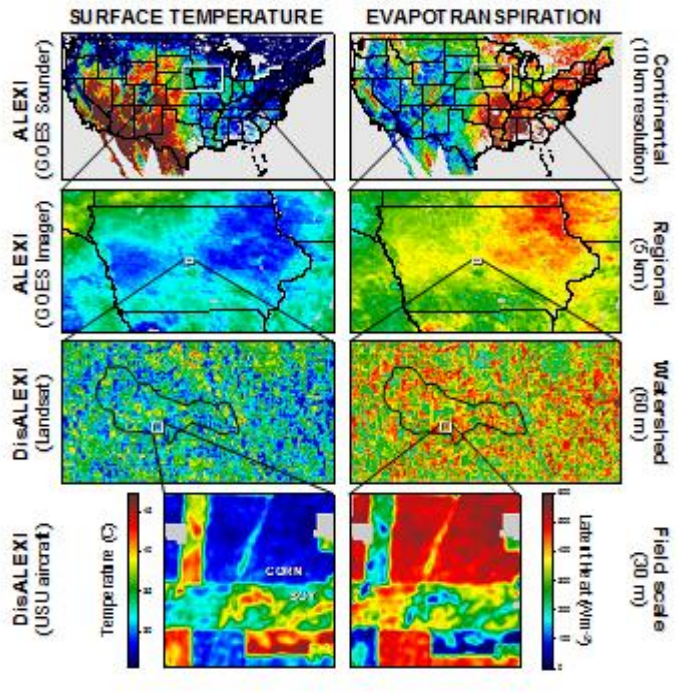
Multispectral Thermal InfraRed (TIR) Scanner

Map of dominant tree species, Bartlett Forest, NH

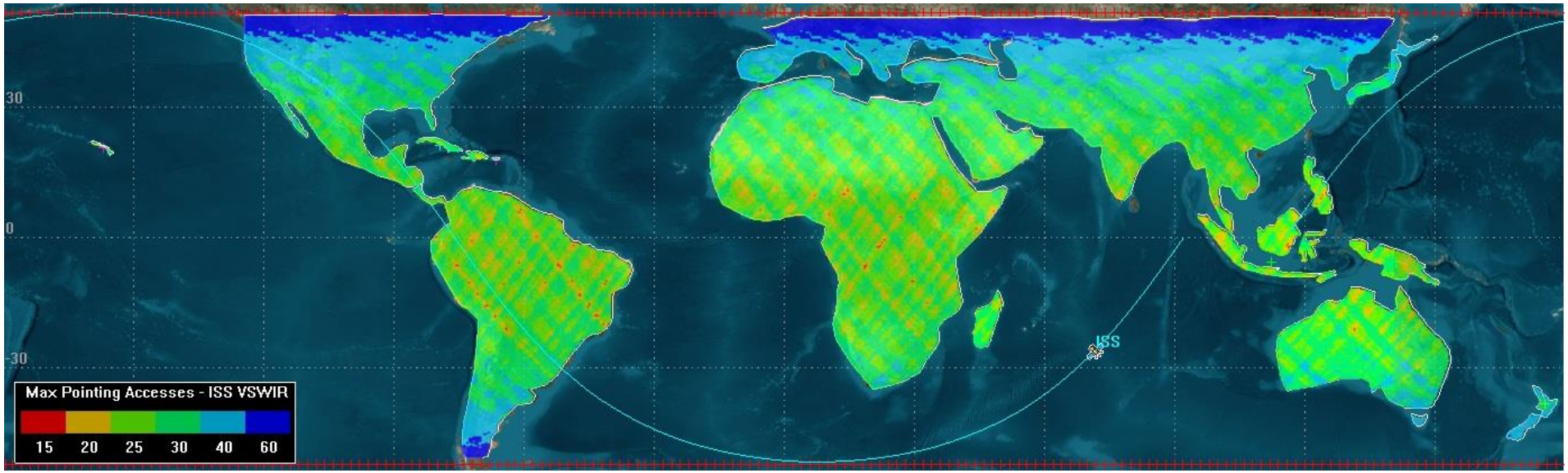


Biochemistry from Spectroscopy

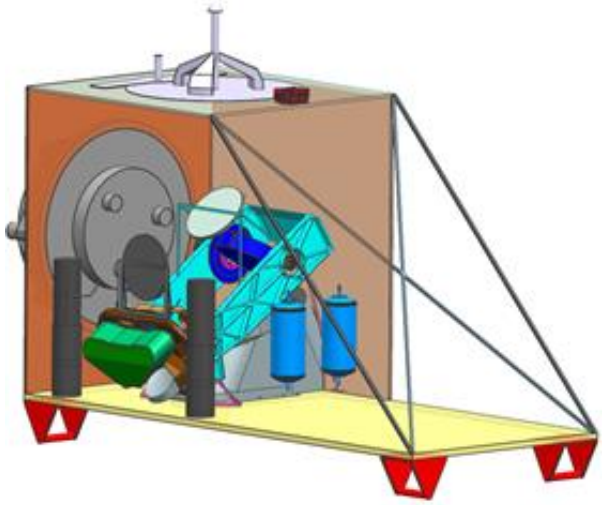




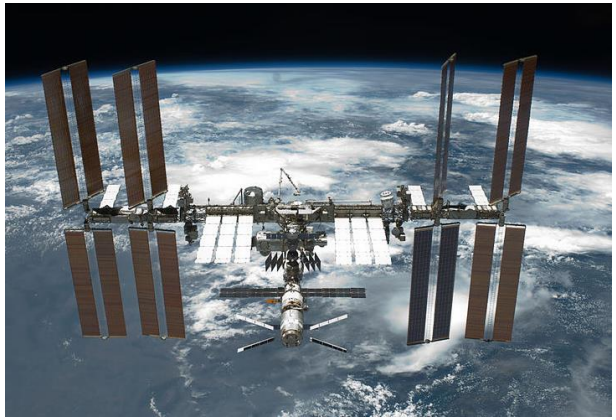
HyspIRI ISS Options



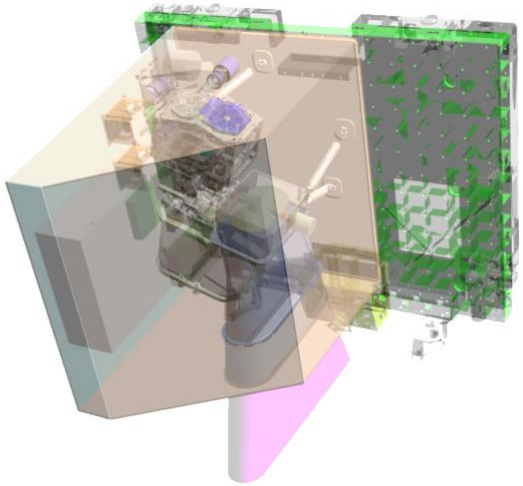
TIR



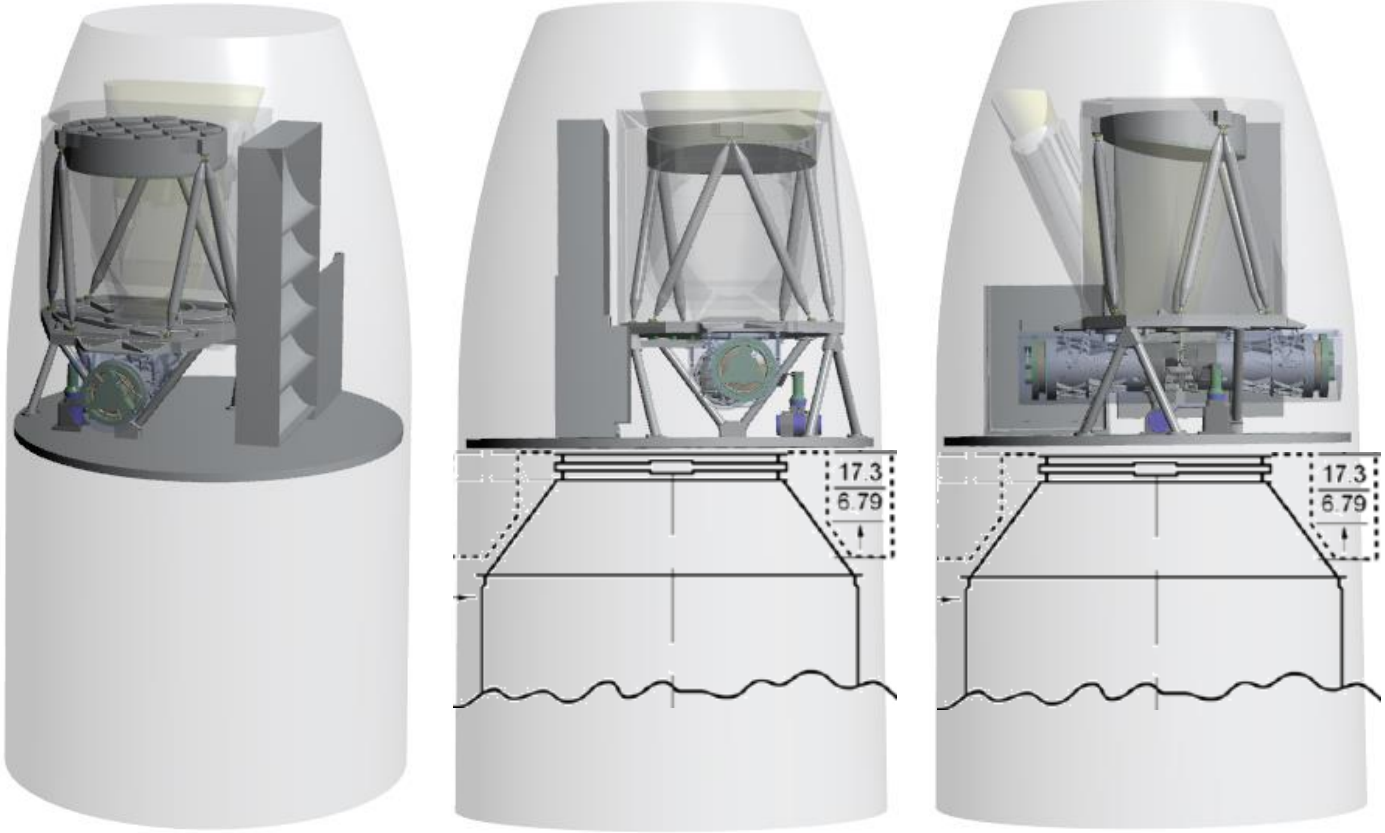
+IPM

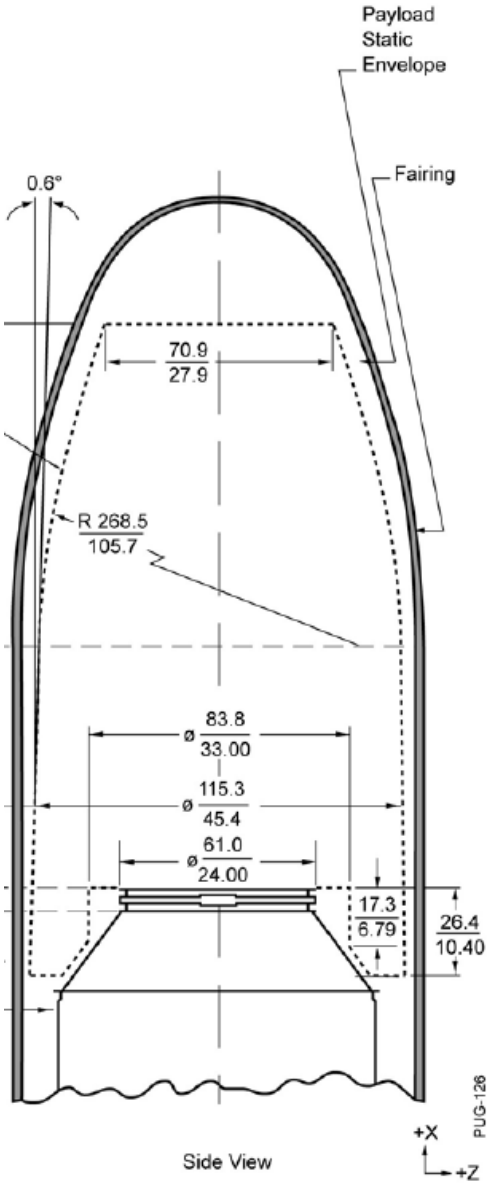


VSWIR



Example HyspIRI SmallSat on Pegasus

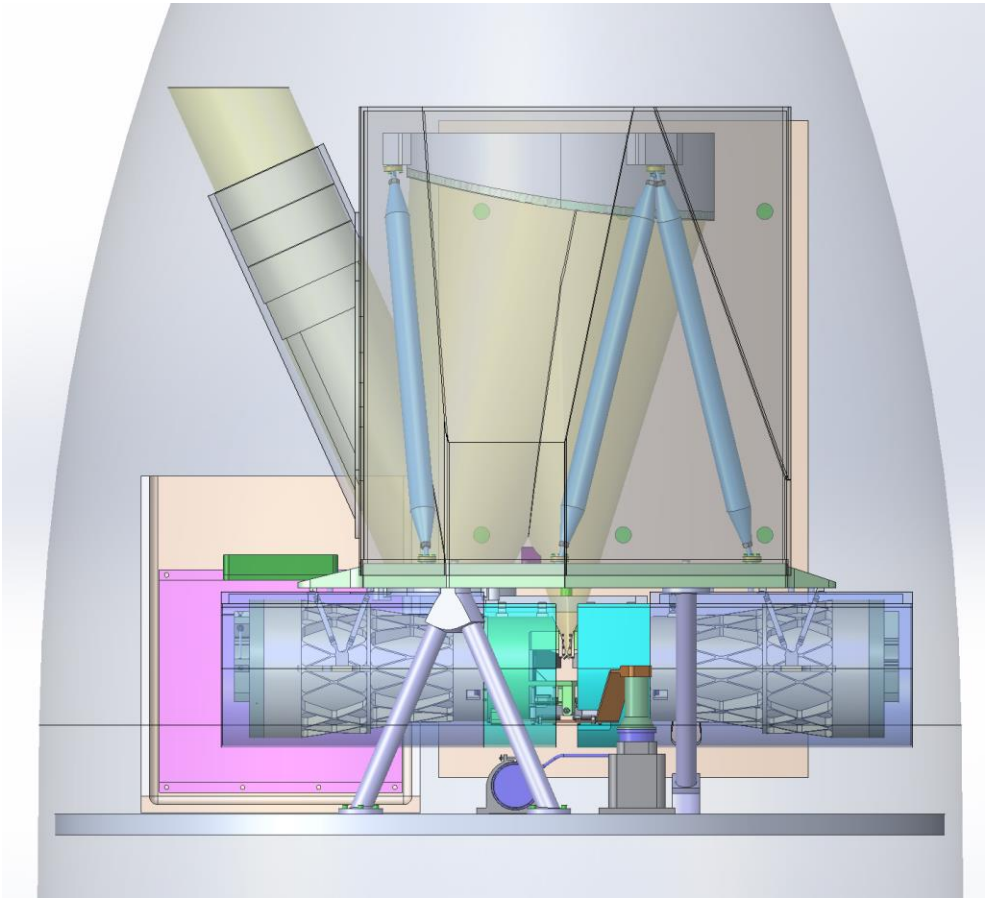




TIR Concept for Pegasus also well advance

Separate SmallSats in Polar Orbit

HyspIRI Small Sat VSWIR for Sustainable Land Imaging

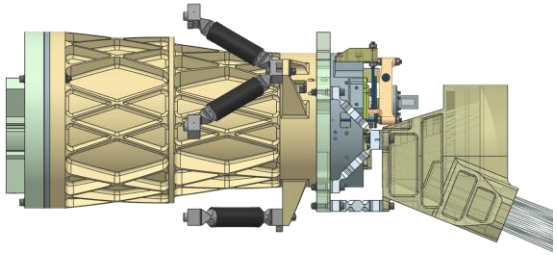


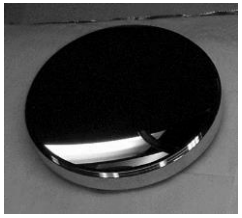
- Spectral range: 380 to 2510 nm
- Spectral sampling: 5 nm

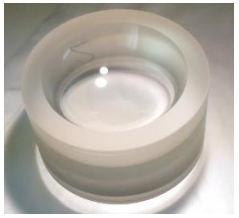
- Radiometric Range: 14 bits to 100% lambertian target
- Radiometric SNR: **F/1.8 high** throughput system

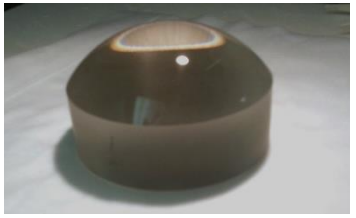
- Spatial sampling: **30 m**
- Spatial cross-track: 6200 samples
- Spatial swath: **16 day revisit**

- Meets HyspIRI VSWIR and support Sustainable Land Imaging



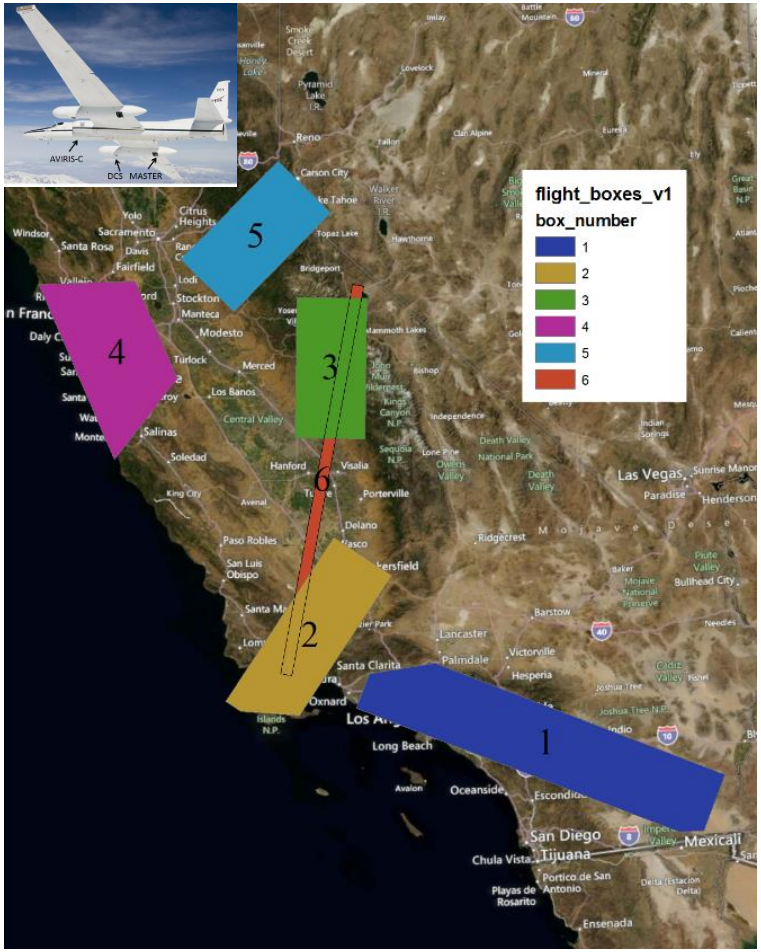




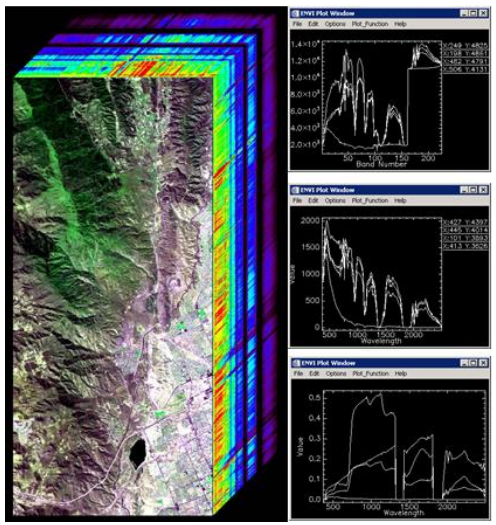


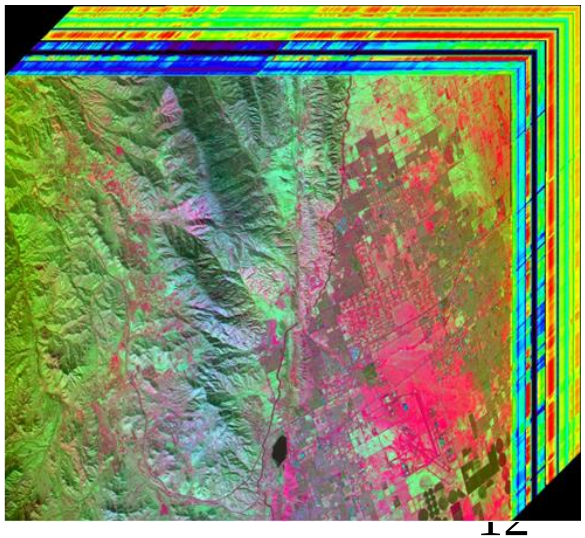
HyspIRI Preparatory Airborne Campaign Third Year Added

- Support R&A HyspIRI Preparatory Science Campaign
  - science team with 14 PIs
  - Delivered Level 1 and Level 2 data products
- Ecosystems, Seasonal, Climate, Coastal, Urban, Resources
- 6 zones, 3 seasons, 2 years



- **Objective: Advance HyspIRI Mission Science, Algorithm and Processing Readiness**
  - *Ecosystem composition, function, biochemistry, seasonality, structure, and modeling*
  - *Coastal ocean phytoplankton functional types, habitat*
  - *Urban land cover, temperature, transpiration*
  - *Surface energy balance*
  - *Atmospheric characterization and local methane sources*
  - *Surface geology, resources, soils, hazards*





HyspIRI Preparatory Airborne Studies

- Harvard/Paul Moorcroft - Linking Terrestrial Biosphere Models with Imaging Spectrometry Measurements of Ecosystem Composition, Structure, and Function
- UC Santa Barbara/Dar Roberts - HyspIRI discrimination of plant species and functional types along a strong environmental-temperature gradient
- UWI/Philip Townsend - Measurement of ecosystem metabolism across climatic and vegetation gradients in California for the 2013-2014 NASA AVIRIS/MASTER airborne campaign
- UC Davis/Susan Ustin - Identification of Plant Functional Types By Characterization of Canopy Chemistry Using an Automated Advanced Canopy Radiative Transfer Model
- Sonoma State/Matthew Clark - Spectral and temporal discrimination of vegetation cover across California with simulated HyspIRI imagery
- NRL/Bo-Cai Gao - Characterization and Atmospheric Corrections to the AVIRIS-Classic and AVIRISng Data to Support the HyspIRI Preparatory Airborne Activities
- USGS/Bernard Hubbard - Using simulated HyspIRI data for soil mineral mapping, relative dating and flood hazard assessment of alluvial fans in the Salton Sea basin, Southern California
- UC Riverside/George Jenerette - Assessing Relationships Between Urban Land Cover, Surface Temperature, and Transpiration Along a Coastal to Desert Climate Gradient
- NEON/Thomas Kampe - Synergistic high-resolution airborne measurements of ecosystem structure and process at NEON sites in California
- UC Santa Cruz/Raphael Kudela - Using HyspIRI at the Land/Sea Interface to Identify Phytoplankton Functional Types
- Bubbleology/Ira Leifer - Hyperspectral imaging spectroscopic investigation of California natural and anthropogenic fossil methane emissions in the short-wave and thermal infrared
- UMD/Shunlin Liang - Characterizing surface energy budget of different surface types under varying climatic conditions from AVIRIS and MASTER data
- RIT/Jan van Aardt - Investigating the impact of spatially-explicit sub-pixel structural variation on the assessment of vegetation structure from HyspIRI data
- UNV/Wendy Calvin - Energy and Mineral Resources: Surface composition mapping that identifies resources and the changes and impacts associated with their development

Recent HyspIRI Related Papers

Emmanuel C. Devred, Kevin R. Turpie, Victor V. Klemas, Tiffany Moisan, Wesley Moses, Marcel Babin, Marie-Hélène Forget, Gerardo Toro-Farmer, Young-Heon Jo, "Future Retrievals of Water Column Bio-Optical Properties using the Hyperspectral Infrared Imager (HyspIRI)" (submitted to Remote Sensing)

Wright, R., H. Garbeil, and Davies, A.G., (2010). Cooling rate of some active lavas determined using an orbital imaging spectrometer. Journal of Geophysical Research (Solid Earth), 115, B06205, doi:10.1029/2009JB006536.

Koeppen, W.C., Patrick, M., Orr, T., Sutton, J., Dow, D., and Wright, R. (2013). Constraints on the partitioning of Kilauea's lavas between surface and tubed flows, estimated from infrared satellite data, sulfur dioxide flux measurements, and field observations. Bulletin of Volcanology, 75, doi:10.1007/s00445-013-0716-3

Wright, R., Glaze, L., and Baloga, S.M., (2011). Constraints on determining the eruption style and composition of terrestrial lavas from space. Geology, 39, 1127-1130

Serbin, S.P., Singh, A., McNeil, B.E., Townsend, P.A., (in review). Spectroscopic determination of leaf morphological, nutritional, and biochemical traits for northern temperate and boreal tree species. Oecologia

Banskota, A., Wynne, R.H., Thomas, V.A., Serbin, S.P., Kayastha, N., Gastellu-Etchegorry, J.P., Townsend, P.A. (2013). Investigating the Utility of Wavelet Transforms for Inverting a 3-D Radiative Transfer Model Using Hyperspectral Data to Retrieve Forest LAI. Remote Sensing, 5(6), 2639-2659. DOI: 10.3390/rs5062639

Banskota, A., Wynne, R.H., Serbin, S.P., Kayastha, N., Thomas, V.A., Townsend, P.A. (2013). Utility of the wavelet transform for LAI estimation using hyperspectral data. Photogrammetric Engineering & Remote Sensing, 79(7), 653-662

Ainsworth, E.A., Serbin, S.P., Skoneczka, J.A., Townsend, P.A. (2013). Using leaf optical properties to detect ozone effects on foliar biochemistry. Plant Physiology, DOI: 10.1007/s11120-013-9837-y

Bernacchi, C.J., Bagely, J.E., Serbin, S.P., Ruiz-Vera, U.M., Rosenthal, D.M., Vanloocke, A. (2013). Modeling C3 photosynthesis from the chloroplast to the ecosystem. Plant, Cell & Environment, DOI: 10.1111/pce.12118

Couture, J.J., Serbin, S.P., and Townsend, P.A. (2013). Spectroscopic sensitivity of real-time, rapidly induced phytochemical change in response to damage. New Phytologist, 198(1), 311-319. DOI: 10.1111/nph.12159

Townsend, P.A., Serbin, S.P., Kruger, E.L., Gamon, J. (2013). Disentangling the contribution of biological and physical properties of leaves and canopies in imaging spectroscopy data. Proceedings of the National Academy of Sciences (PNAS),

Deel, L. N., B. E. McNeil, P. G. Curtis, S. P. Serbin, A. Singh, K. N. Eshleman, and P. A. Townsend. 2012. Relationship of a Landsat cumulative disturbance index to canopy nitrogen and forest structure. Remote Sensing of Environment, 118, 40-49.

Serbin, S.P., Dillaway, D., Kruger, E.L., Townsend, P.A. (2012). Leaf optical properties reflect variation in photosynthetic metabolism and its sensitivity to temperature. Journal of Experimental Botany, 63, 489-502. DOI: 10.1093/jxb/err294

Schaaf, A.N., Dennison, P.E., Fryer, G.K., Roth, K.L., and Roberts, D.A., 2011, Mapping Plant Functional Types at Multiple Spatial Resolutions using Imaging Spectrometer Data, GIScience and Remote Sensing, 48 (3), 324-344.

Roberts, D.A., Quattrochi, D.A., Hulley, G.C., Hook, S.J. and Green, R.O., 2012, Synergies between VSWIR and TIR data for the urban environment: An evaluation of the potential for the Hyperspectral Infrared Imager (HyspIRI) Decadal Survey mission, Remote Sens. Environ., 117, 83-101.

Roth, K.L., Dennison, P.E., and Roberts, D.A., 2012, Comparing endmember selection techniques for accurate mapping of plant species and land cover using imaging spectrometer data, Remote Sens. Environ., 139-152.

Roberts, D.A., Dennison, P., Roth K., Hulley, G., 2013, RELATIONSHIPS BETWEEN SPECIES COMPOSITION, FRACTIONAL COVER AND LAND SURFACE TEMPERATURE IN A MEDITERRANEAN ECOSYSTEM, Proceedings of Whispers, 2013, Gainesville Florida, 4 pp.

Thorpe, A.K., Roberts, D.A., Bradley, E.S., Funk, C.C., Dennison, P.E., and Leifer, I., in press, High resolution mapping of methane emissions from marine and terrestrial sources using a Cluster-Tuned Matched Filter technique and imaging spectrometry, Remote Sens. Environ., in press.

Bradley, E., Leifer, I., Roberts, D.A., Dennison, P.E., and Washburn, L., 2011, Detection of Marine Methane Emissions with AVIRIS Band Ratios, Geophysical Research Letters, 38, L10702, doi:10.1029/2011GL046729.

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HyspIRI Comprehensive Mission Report to Be Completed by September 2014

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